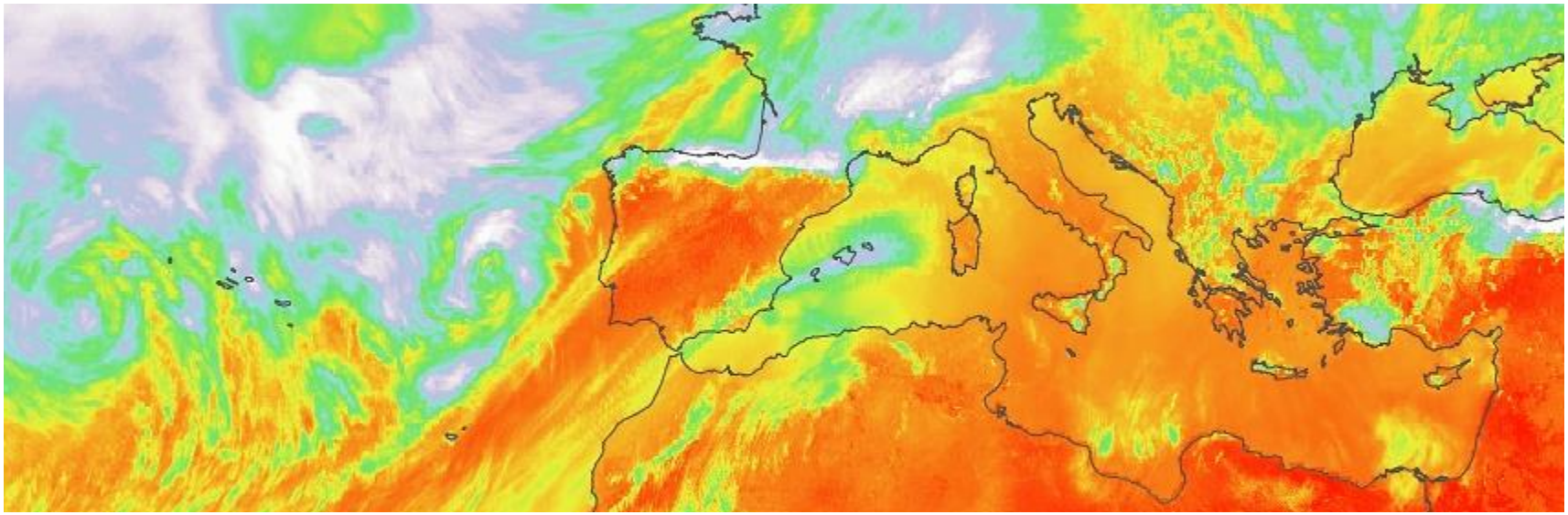
CM SAF

Deutscher Wetterdienst
Wetter und Klima aus einer Hand
DWD

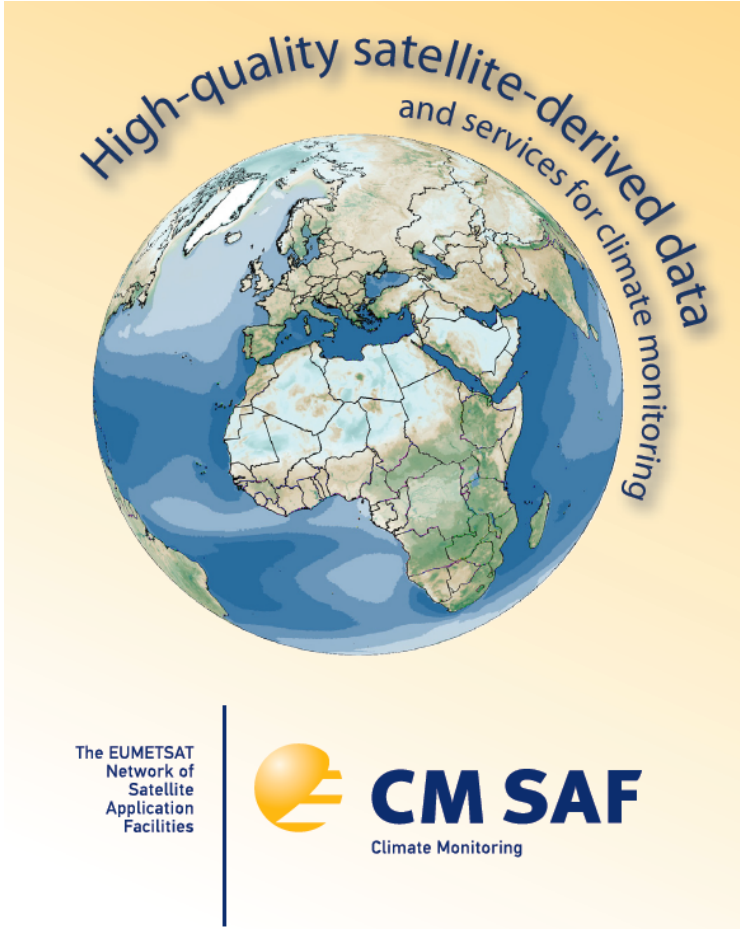
Trends and Variability of Surface Solar Radiation based on satellite-derived CM SAF Climate Data Records

Jörg Trentmann, Steffen Kothe, Richard Müller,
Uwe Pfeifroth, Arturo Sanchez-Lorenzo



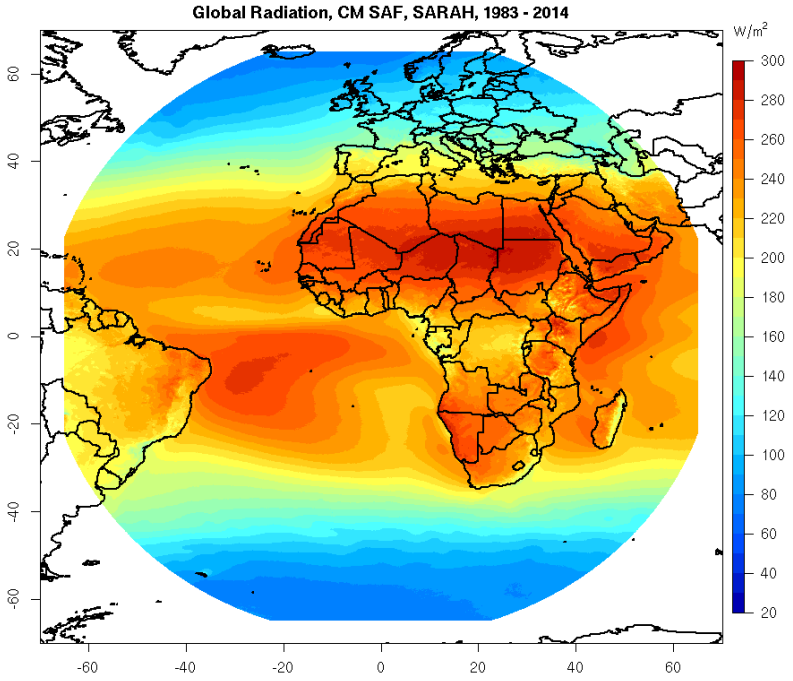
EUMETSAT Satellite Application Facility on Climate Monitoring (www.cmsaf.eu)

- Satellite-based climate data records of regional and global coverage
- Instruments: MVIRI-SEVIRI / GERB + AVHRR + SSM/I-SSMIS
- Surface and ToA radiation, cloud information, surface albedo, water vapor, ocean surface fluxes + precipitation
- Data available: Jan 1982 to October 2016
- Resolutions from 0.03° to 1° and from 15 min to monthly means
- Data freely available: www.cmsaf.eu/wui



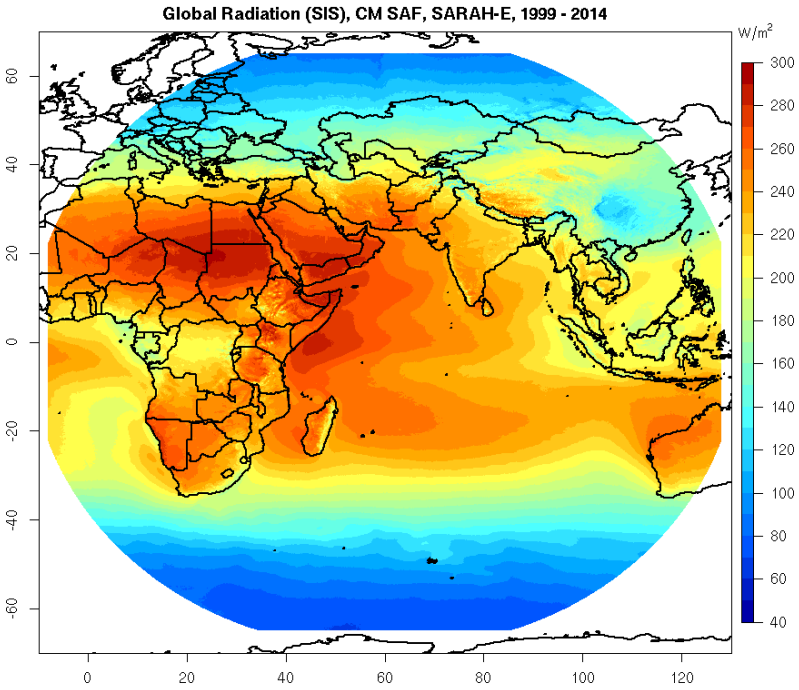
Surface Solar Radiation Dataset – Heliosat (SARAH)

- **Variables**
  - Global irradiance (SIS)
  - Direct (normalized) irradiance (SID, DNI)
  - Effective cloud albedo (CAL)
- **Resolution**
  - Spatial: 0.05° × 0.05°
  - Temporal: hourly, daily, monthly means
- **Coverage**
  - Spatial: Meteosat-Prime Full disk
  - Temporal: 1983 to 2015
- **Satellites / Instruments**
  - Meteosat 2 to 10 (MVIRI/SEVIRI)
- **'Heliosat'-retrieval method**



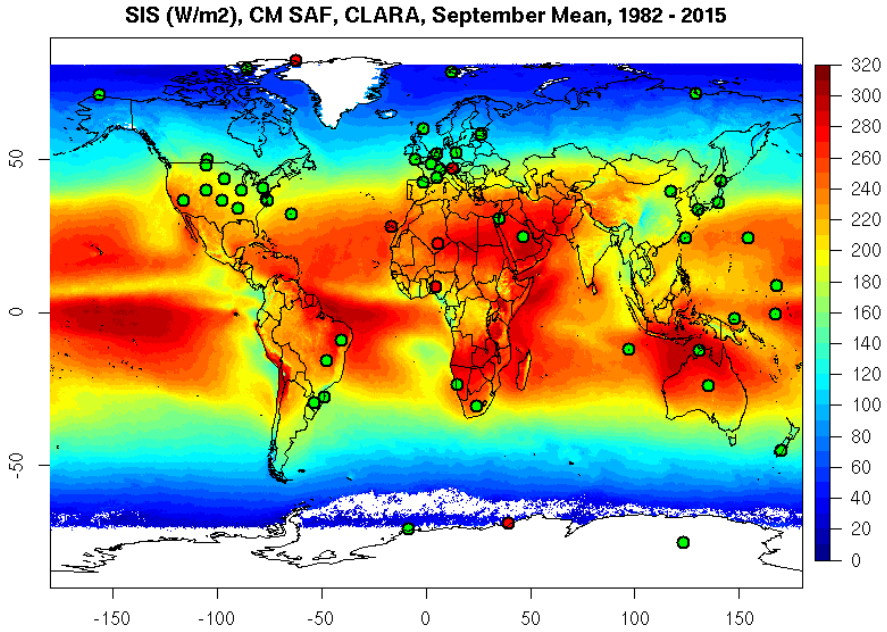
Surface Solar Radiation Dataset – Heliosat (SARAH-E)

- **Variables**
  - Global irradiance (SIS)
  - Direct (normalized) irradiance (SID, DNI)
- **Resolution**
  - Spatial: 0.05° × 0.05°
  - Temporal: hourly, daily, monthly means
- **Coverage**
  - Spatial: Meteosat-~~Prime~~ **IODC** Full disk
  - Temporal: ~~1983~~ **1999** to 2015
- **Satellites / Instruments**
  - Meteosat ~~2 to 10~~ **5 and 7** (MVIRI~~/SEVIRI~~)
- **'Heliosat'-retrieval method**



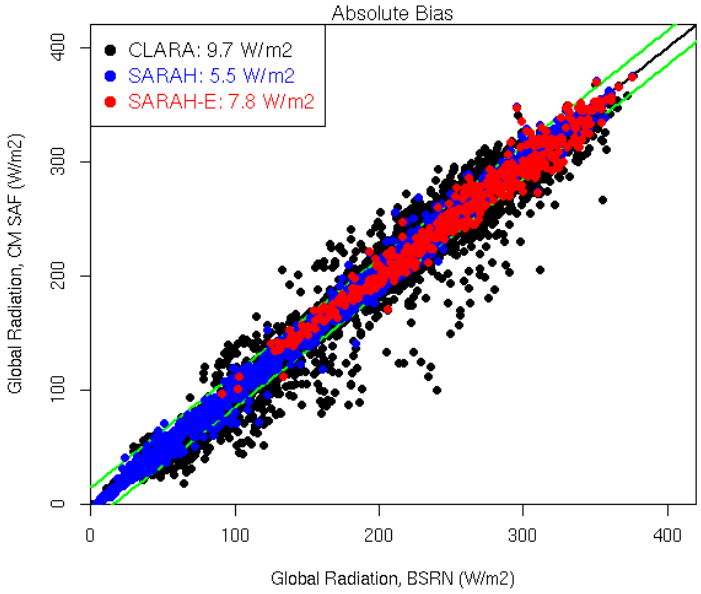
CLARA (Clouds, Albedo, Radiation based on AVHRR)

- **Variables**
  - Global irradiance (SIS)
  - Up- and downwelling longwave (SDL, SOL)
- **Resolution**
  - Spatial: 0.25° × 0.25°
  - Temporal: daily, monthly means
- **Coverage**
  - Spatial: Global
  - Temporal: 1982 to 2015
- **Satellites / Instruments**
  - NOAA / Metop (AVHRR)
- **'Pinker-Laszlo'-look-up-table retrieval method**

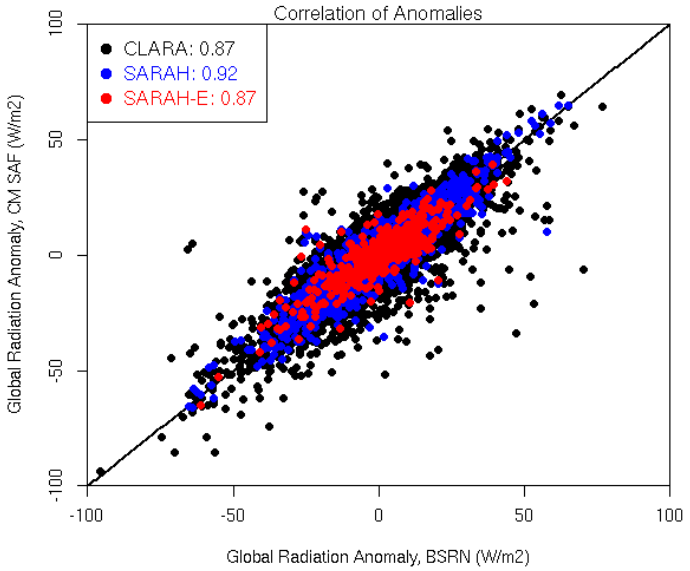


Quality assessment by comparison with BSRN

Accuracy



Suitability for Climate Monitoring

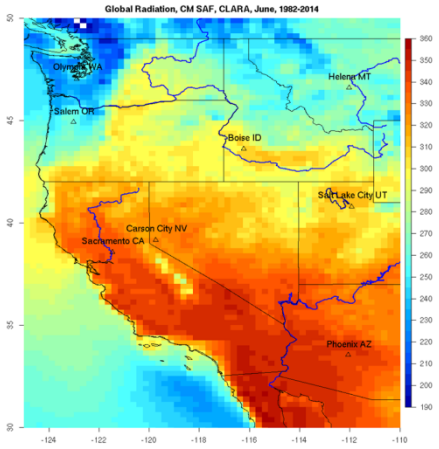


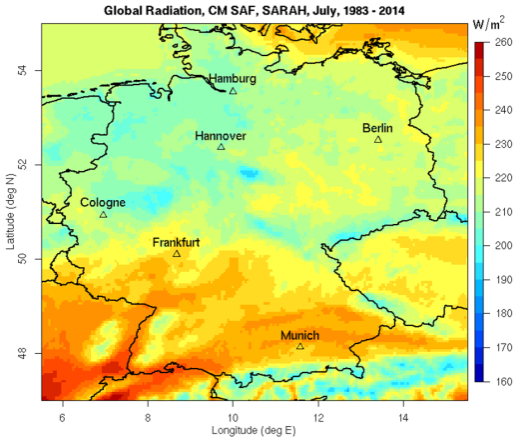
Quality assessment by comparison with BSRN

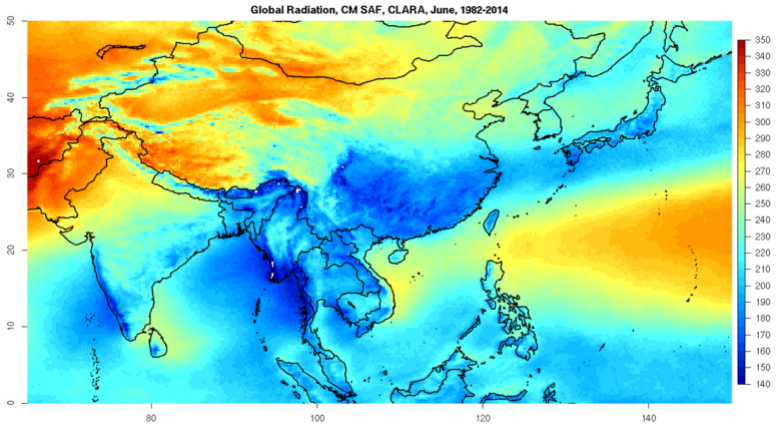
Data	N_{obs}	Bias [W/m²]	MAB [W/m²]	AC
SARAH **1983 – 2015, 0.05°**	1902 *56.111*	0.8 *0.7*	5.5 *11.9*	0.92 *0.95*
SARAH-E **1999 – 2015, 0.05°**	474 *13.717*	-1.6 *-1.7*	7.8 *15.0*	0.87 *0.90*
CLARA **1982 – 2015, 0.25°**	6433 *181.713*	-2.4 *-2.6*	9.7 *19.5*	0.87 *0.89*
CERES SYN1deg **2000 – 2015, 1.0°**	5392 *153.479*	2.4 *2.3*	8.2 *17.5*	0.88 *0.91*

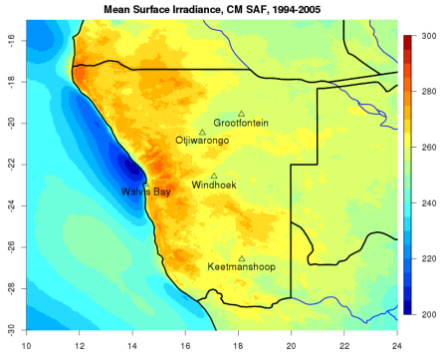
- ➔ Surface Irradiance from CM SAF Climate Data Records is very accurate
- ➔ Compared to CERES: extended temporal coverage, higher spatial resolution

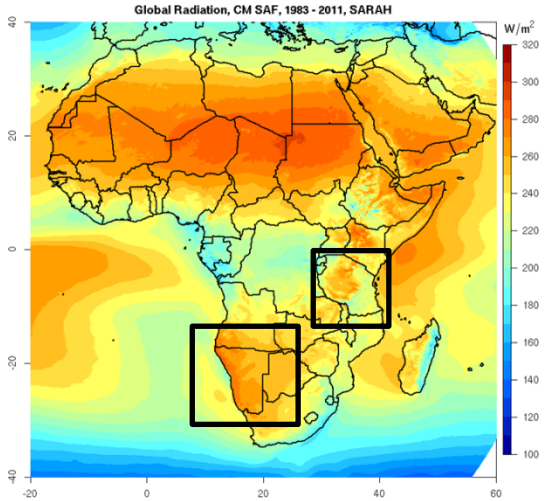
Solar Radiation Climatology

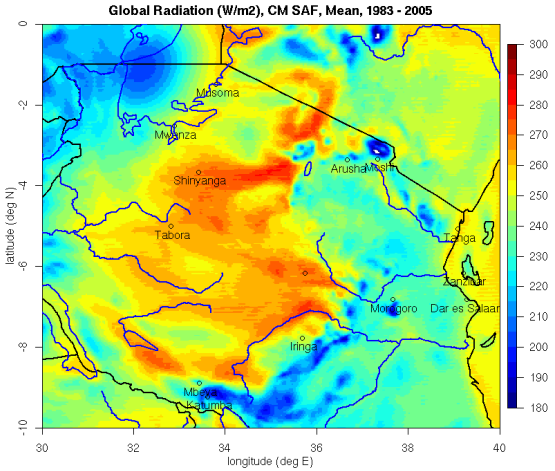




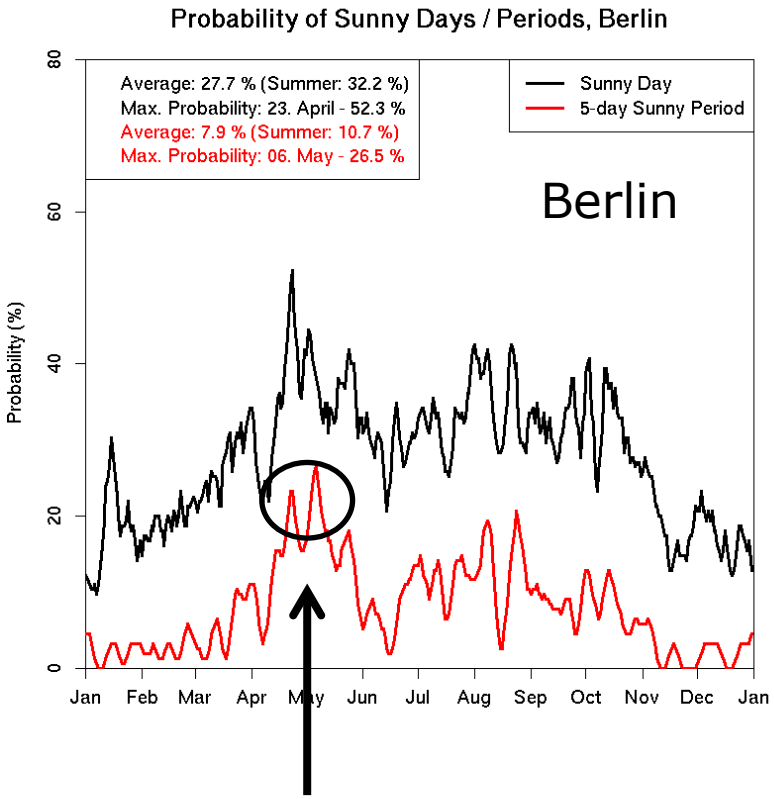






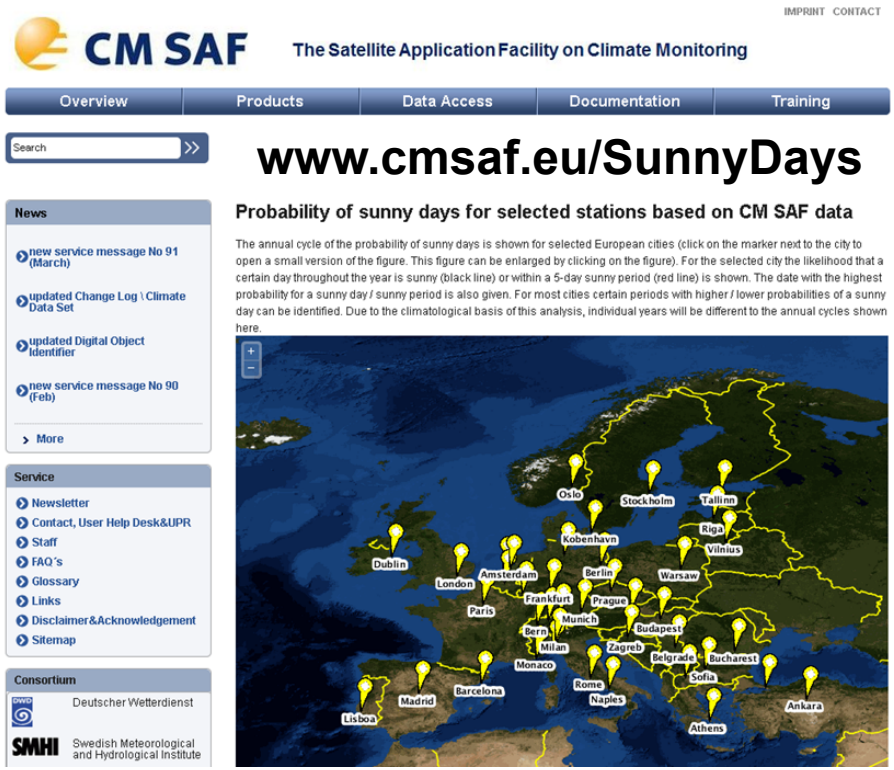


Sunny Days



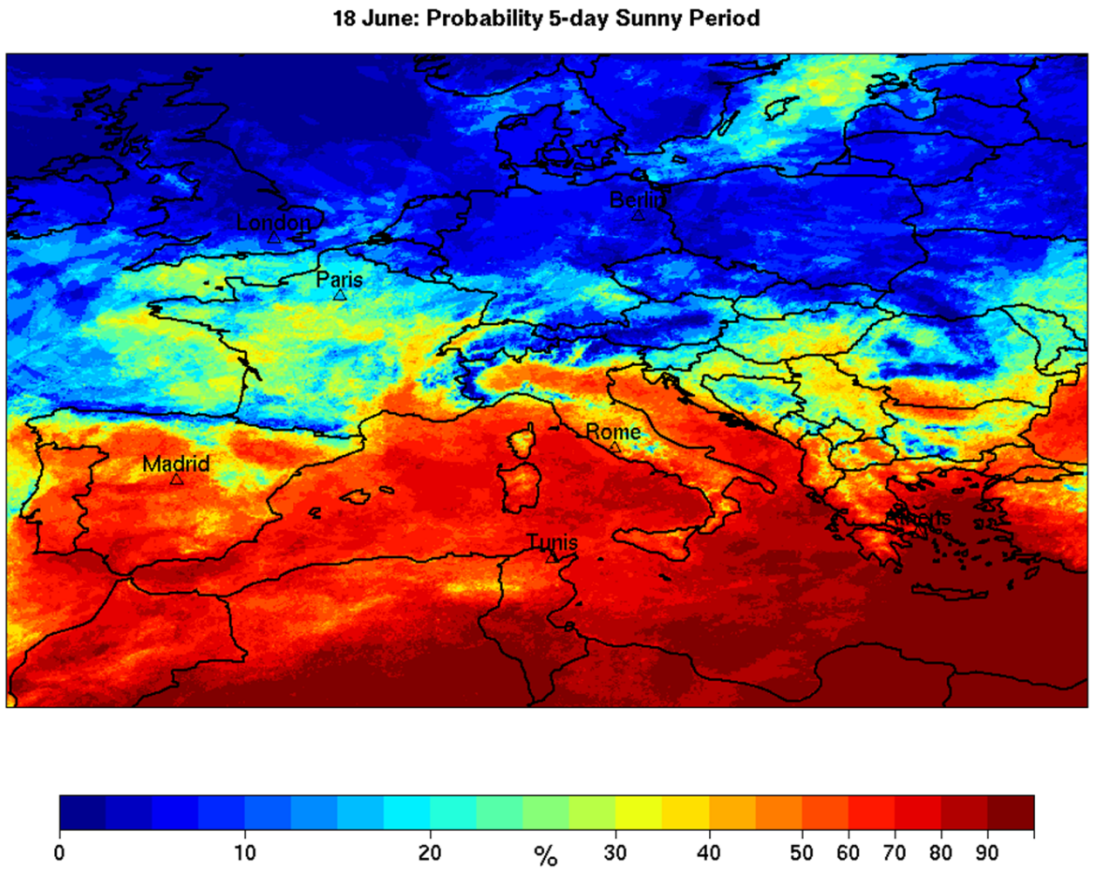
Highest likelyhood of stable, sunny conditions beg. May

Sunny Day: Global radiation larger than 80 % of the clear-sky radiation



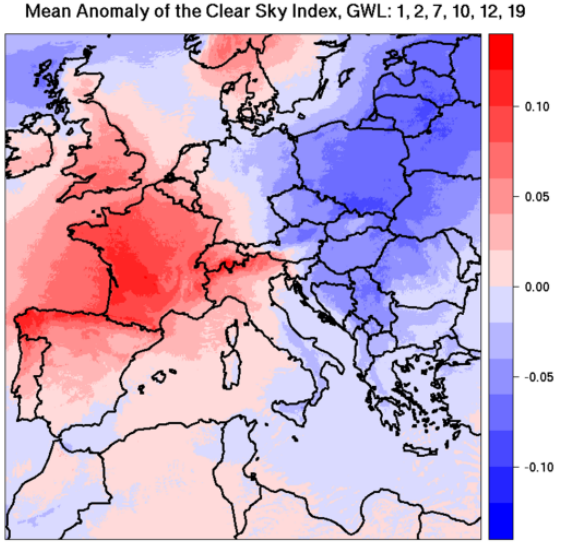
Globally available for many cities!

Where to go in mid June?



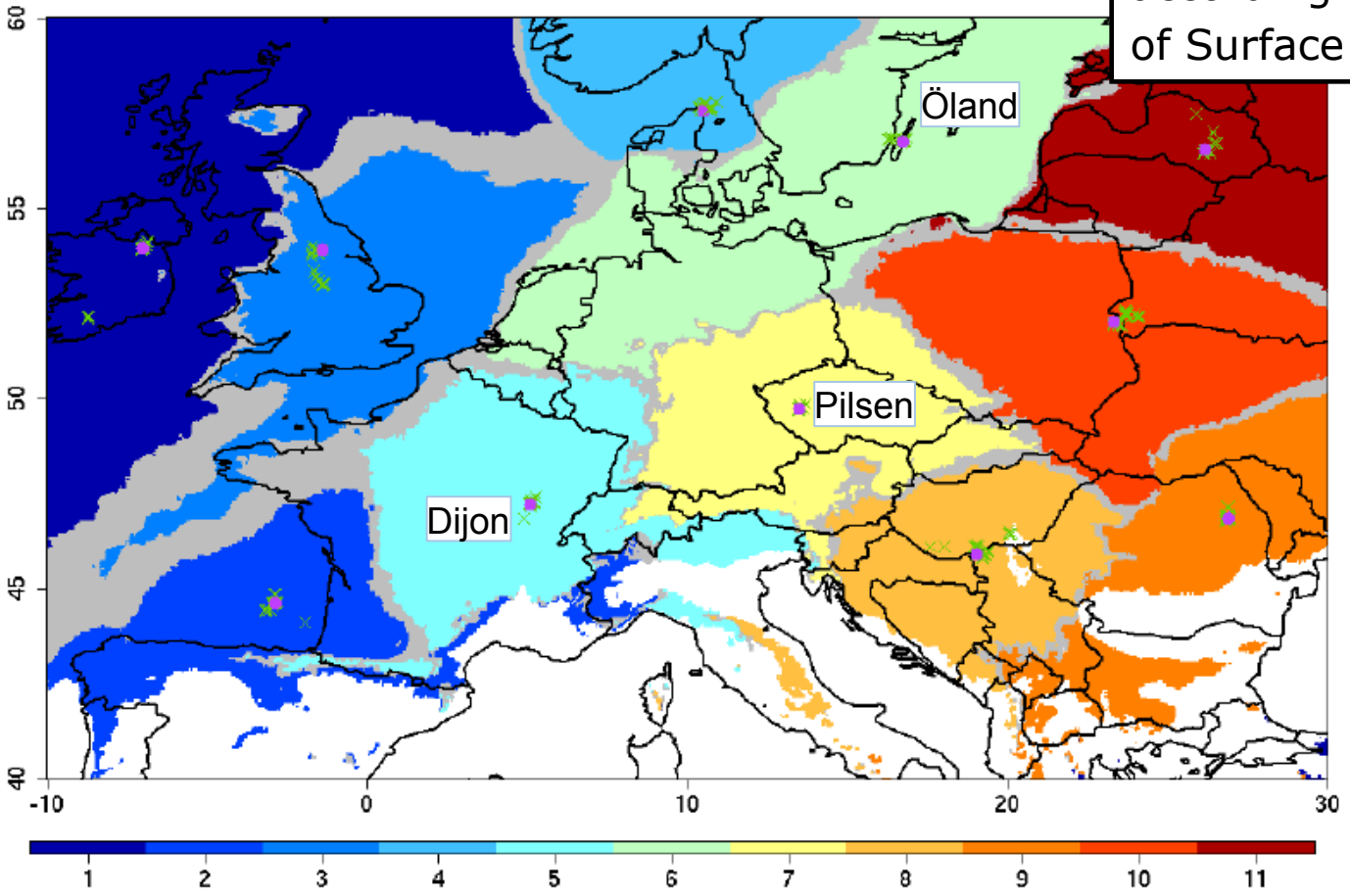
Mid June:

- High probability of sunshine in France / low probability in North-Eastern Europe
- corresponding weather situations more frequent

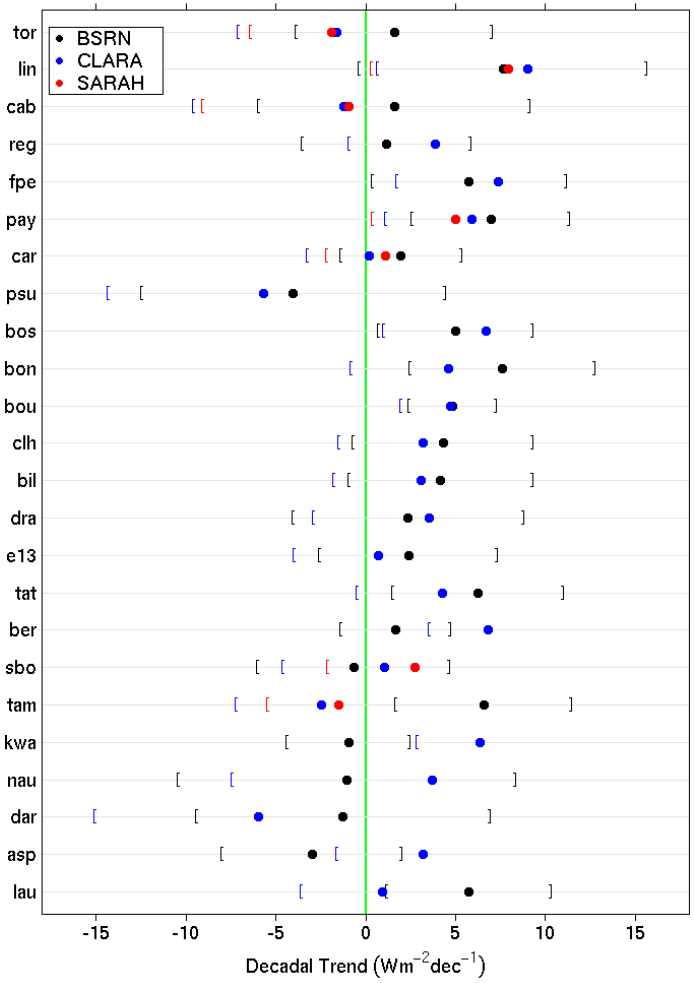


Cluster Analysis of daily irradiance

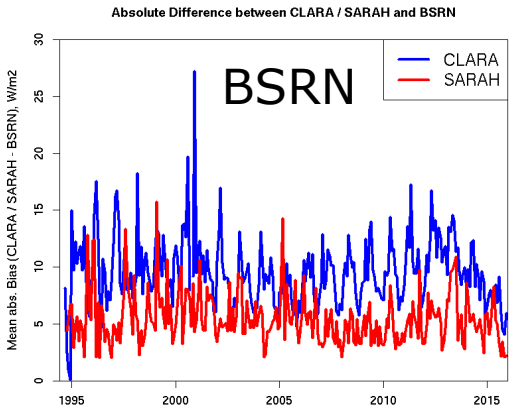
Grouping European Regions according to their variability of Surface Radiation

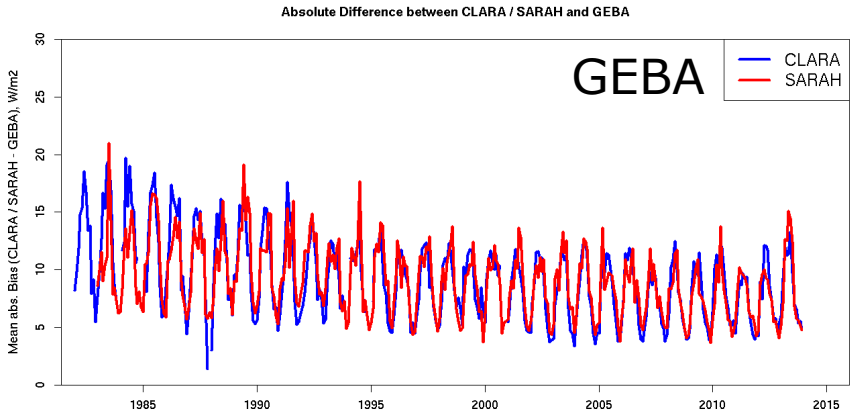


Assessment of temporal stability and trends



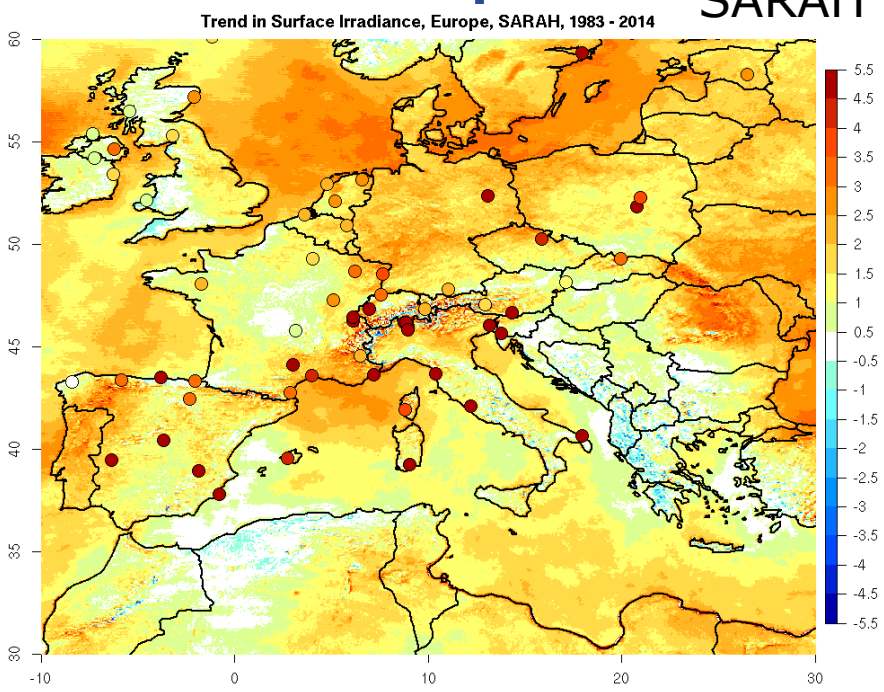
- Accuracy of data records stable compared to BSRN and GEBA
- Temporal trends from BSRN are reproduced.



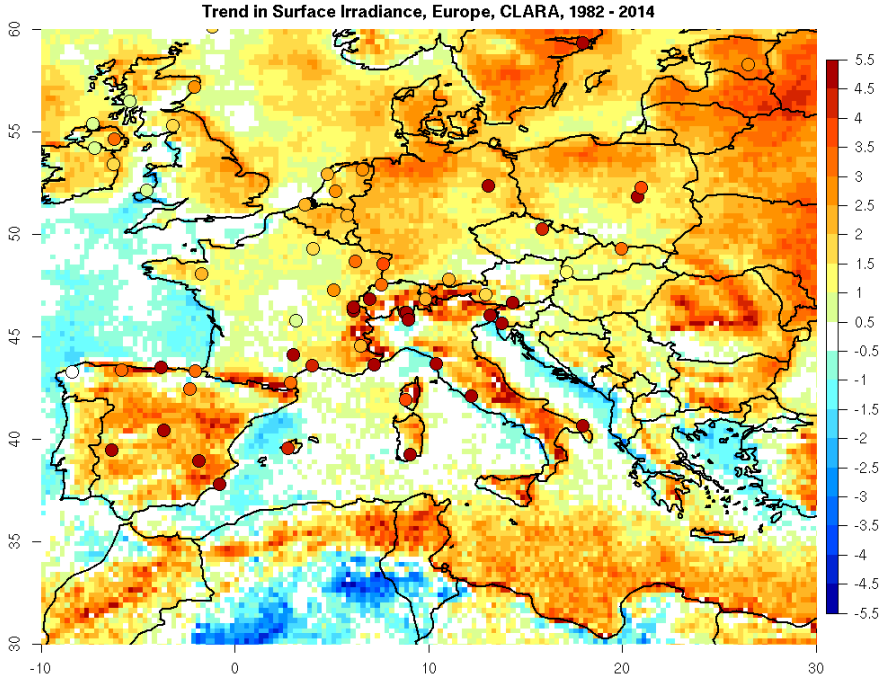


Trends in Europe

SARAH



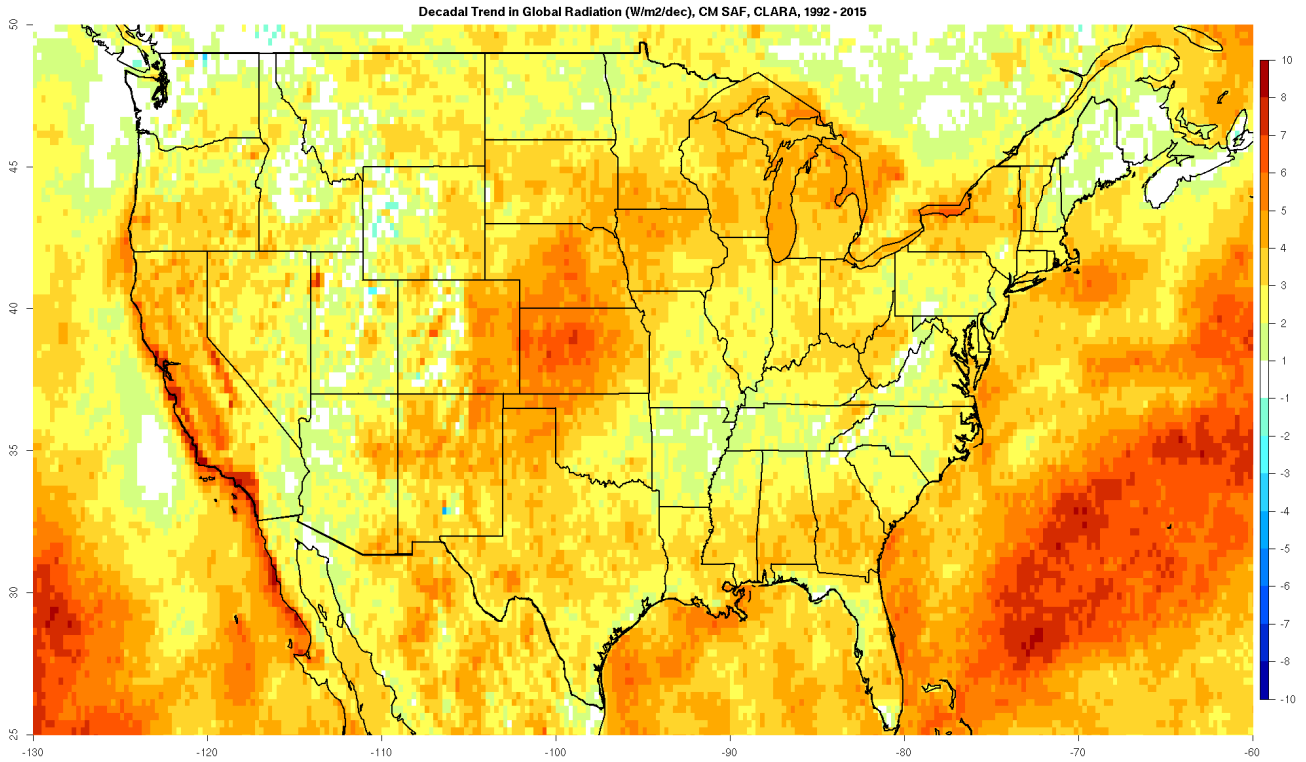
CLARA



- Positive trend of surface irradiance in satellite data records; both data records show consistent patterns
- Substantial spatial variability of the trend (consistent with GEBA)

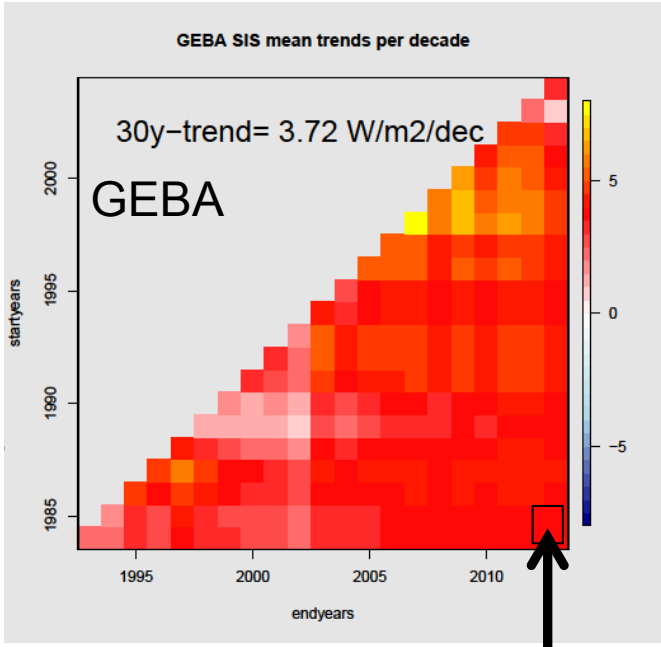
Trend in the US (1992 to 2015)

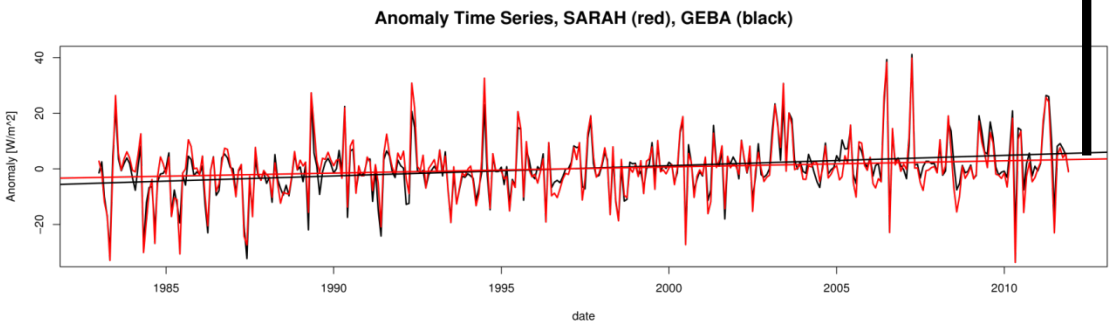
CLARA



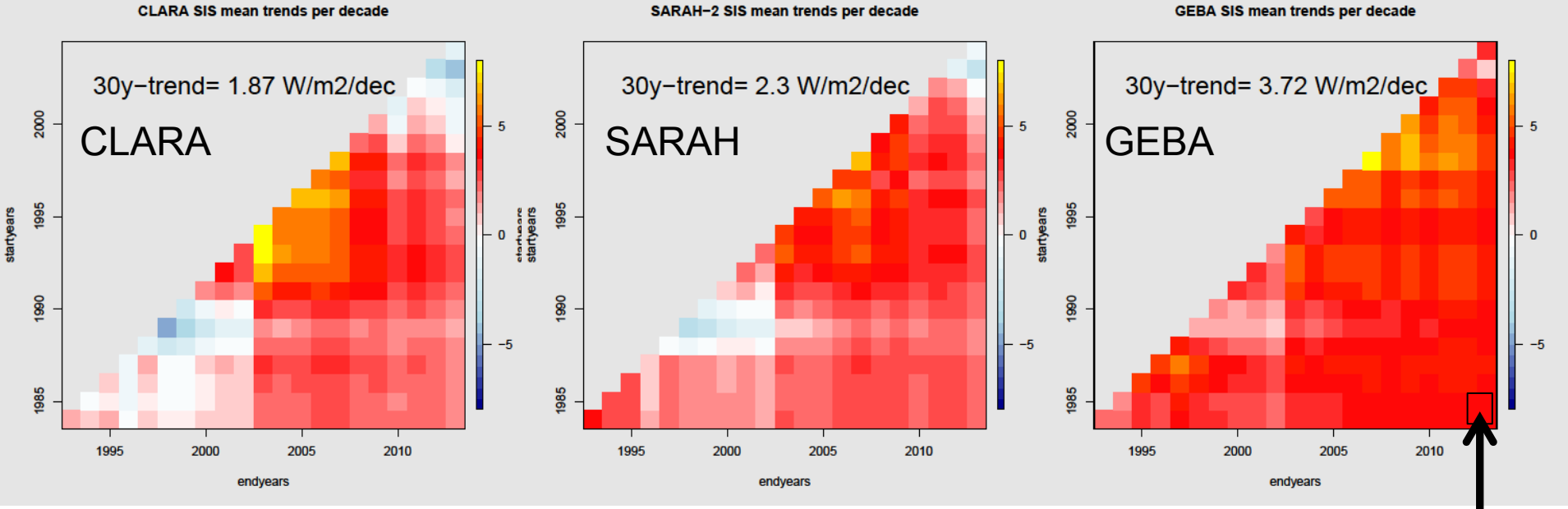
- Strong positive trend of surface irradiance in the CLARA data record with substantial spatial variability

Trend- and Variability-Analysis

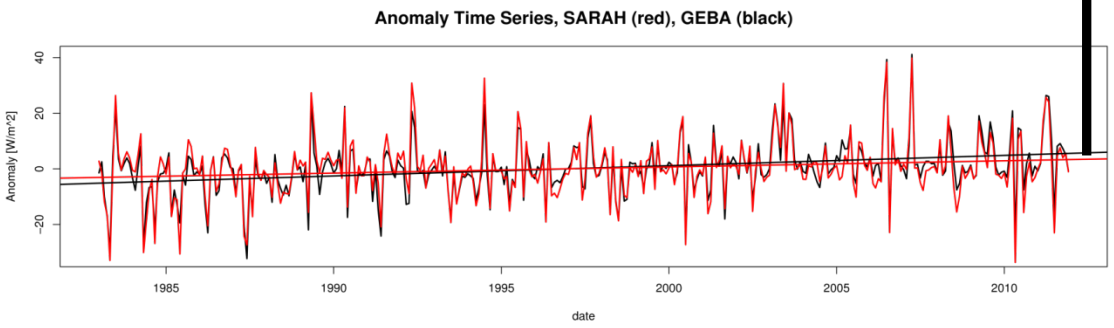




Trend- and Variability-Analysis

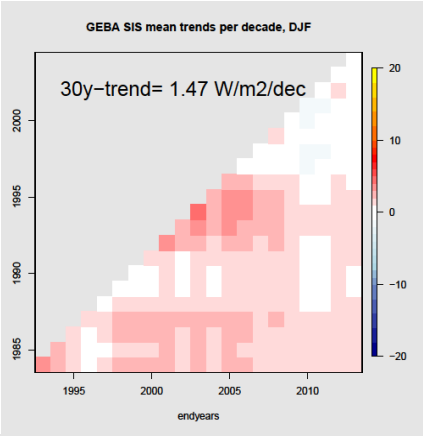


- Substantial temporal variability in decadal trends
- Moderate agreement of satellite- and surface-based estimates
- Satellite tends to underestimate

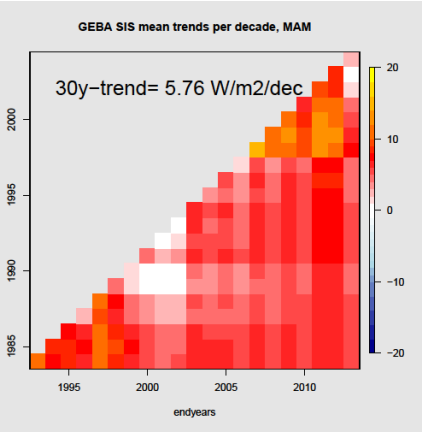


Trend- and Variability-Analysis: Seasonal

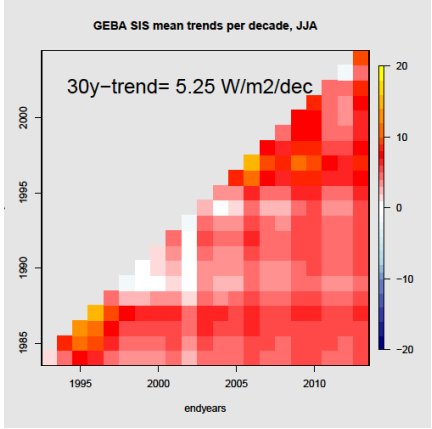
Winter



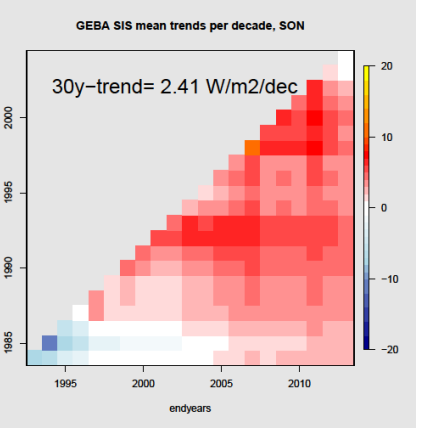
Spring



Summer

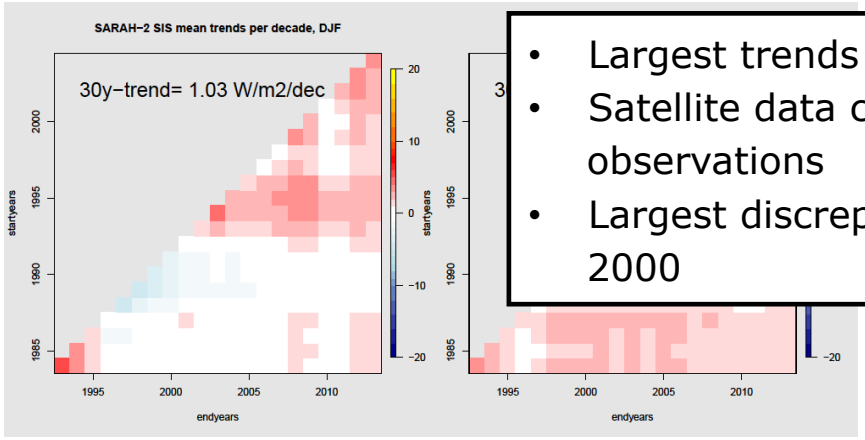


Autumn

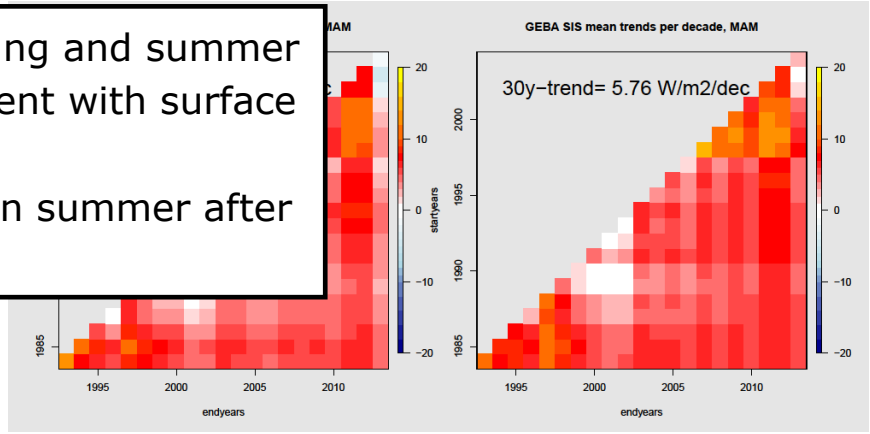


Trend- and Variability-Analysis: Seasonal

Winter

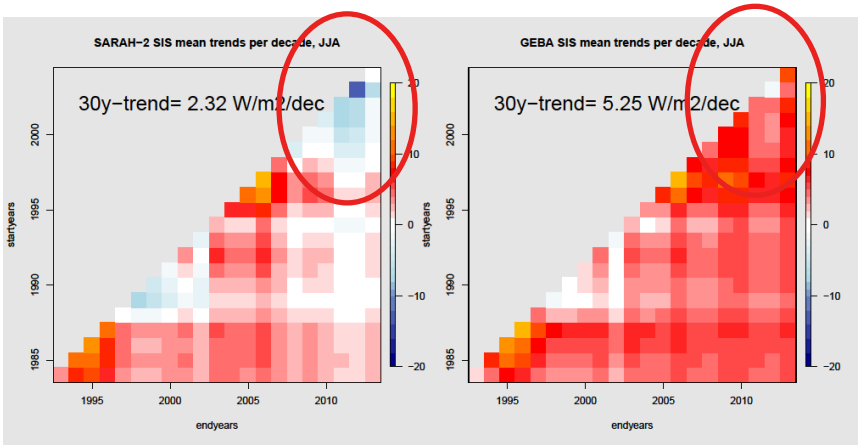


Spring

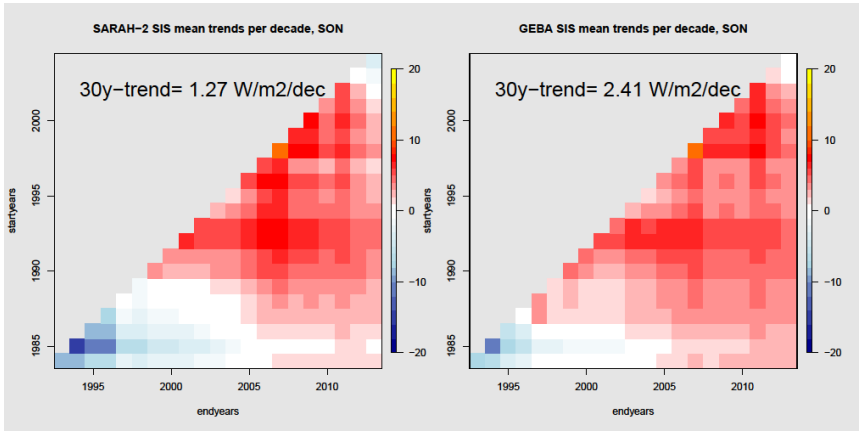


- Largest trends in spring and summer
- Satellite data consistent with surface observations
- Largest discrepancy in summer after 2000

Summer

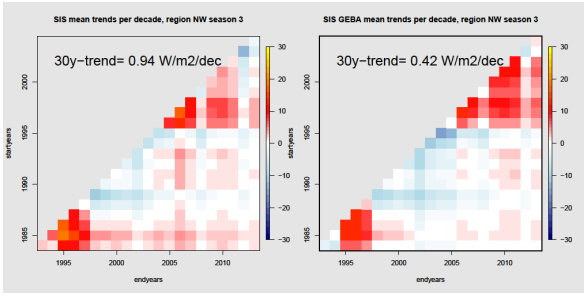


Autumn

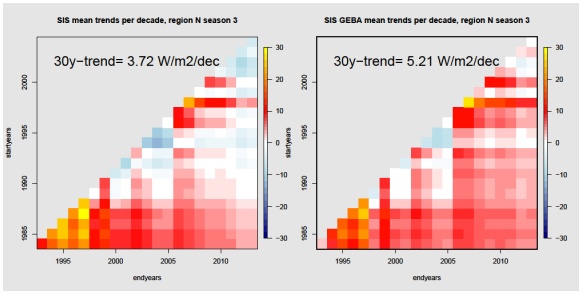


Trend- and Variability-Analysis: Summer, Regional

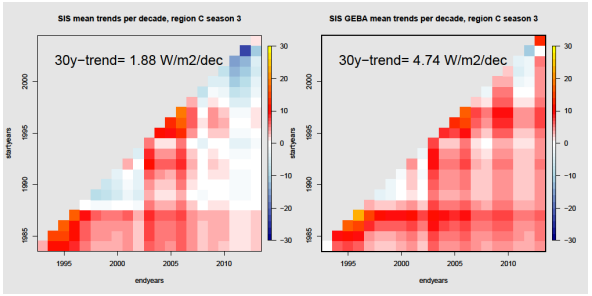
North-West



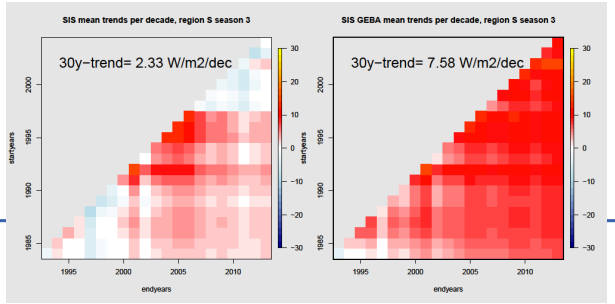
North



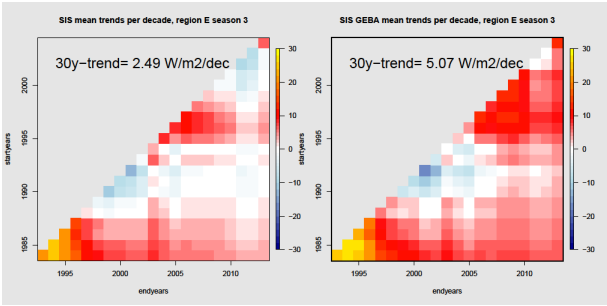
Central



South



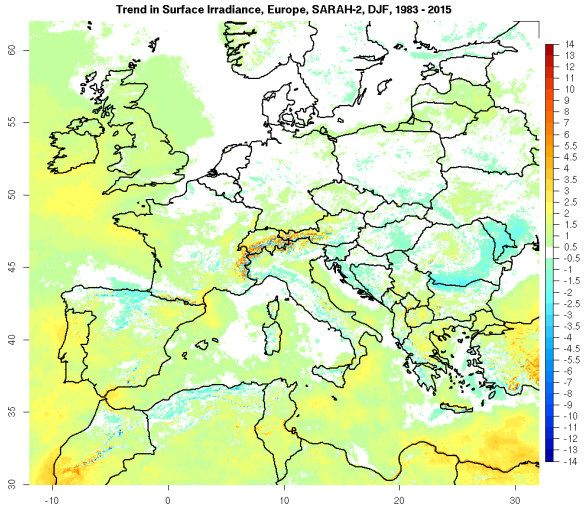
East



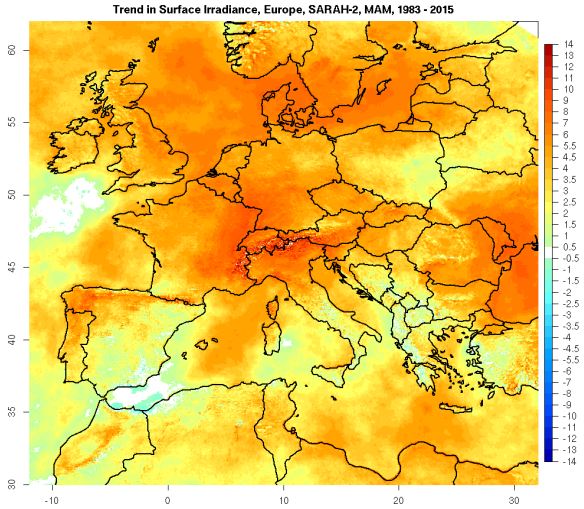
- Decent agreement in summertime variability in Northern Europe
- Increased under-estimation of trend in Eastern / Central / Southern Europe (after 2000)

Trend- and Variability-Analysis: Seasonal

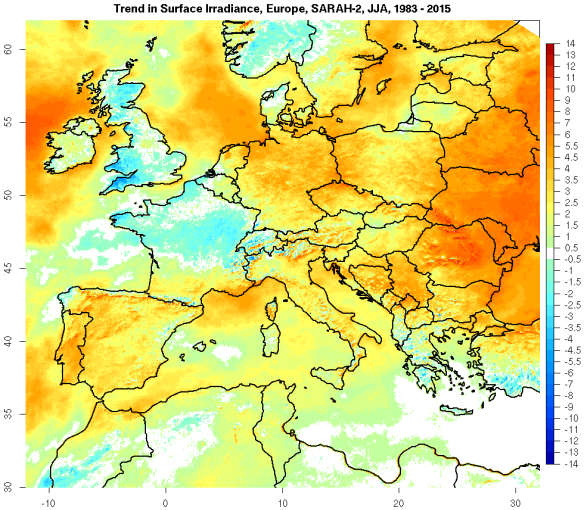
Winter



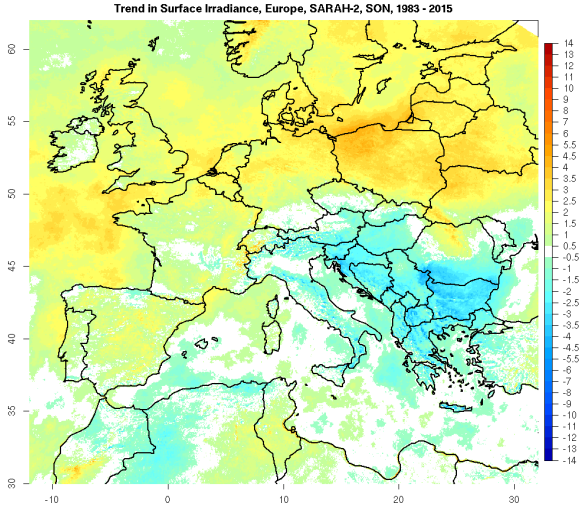
Spring



Summer

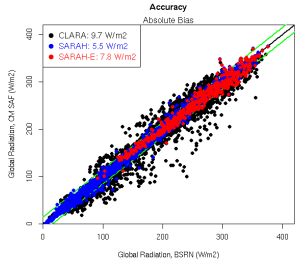


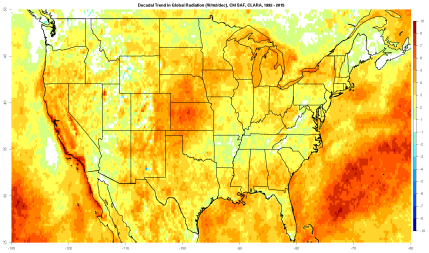
Autumn

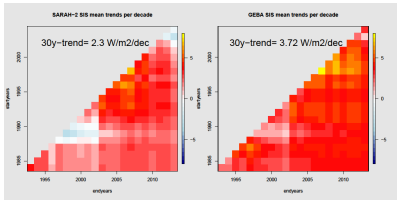


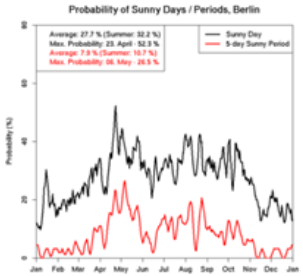
Summary

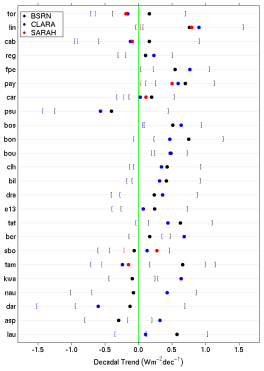
- The CM SAF Surface Solar Radiation data sets (SARAH(-E), CLARA) provide high quality information on the surface solar radiation.
- CM SAF Data Records reproduce the overall temporal trend and spatial variability (in Europe)
- Go to Berlin in May!
- Underestimation of the brightening by the satellite data records in Central / Southern Europe after 2000.

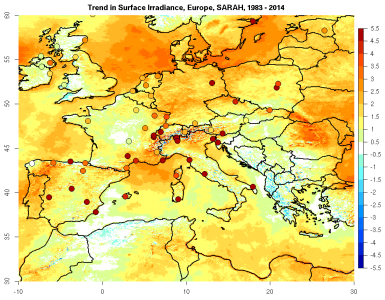








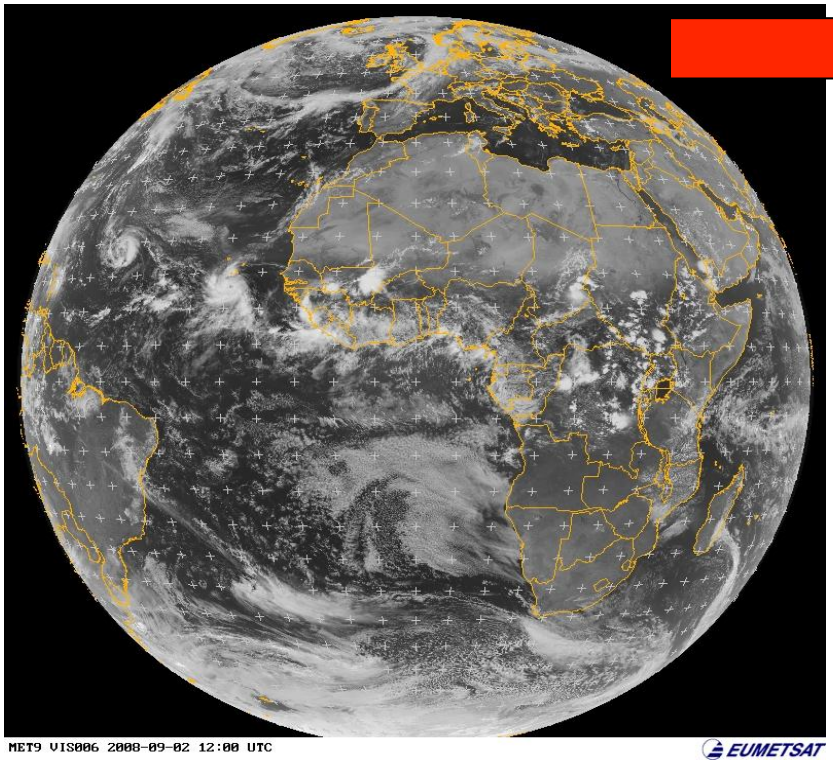




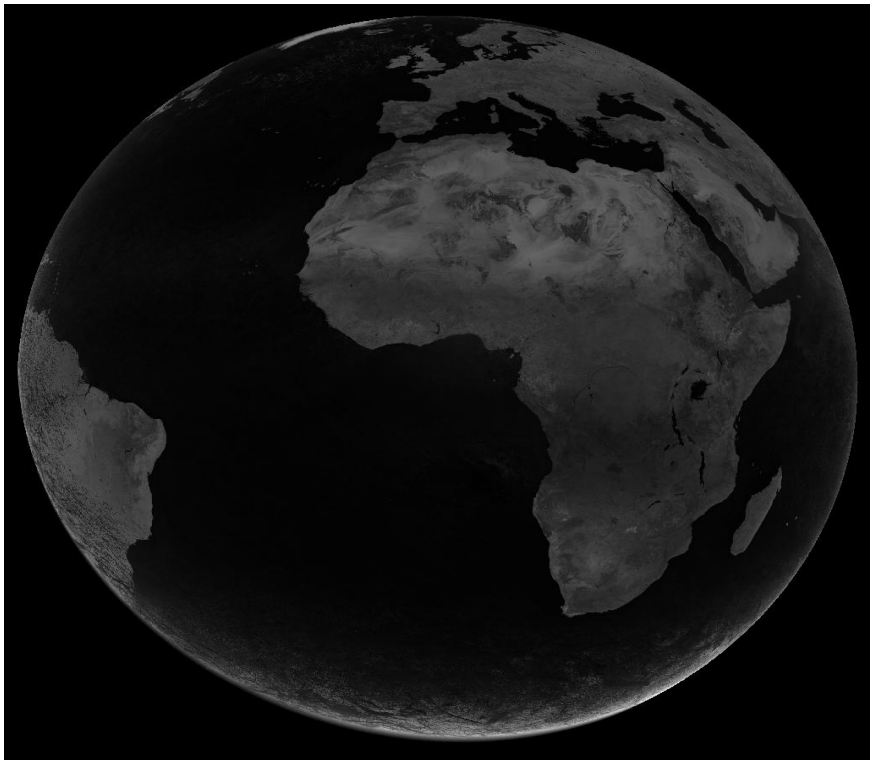
Extra Slides

The Heliosat method

Reflectivity, 12 UTC, 2 Sept 2008

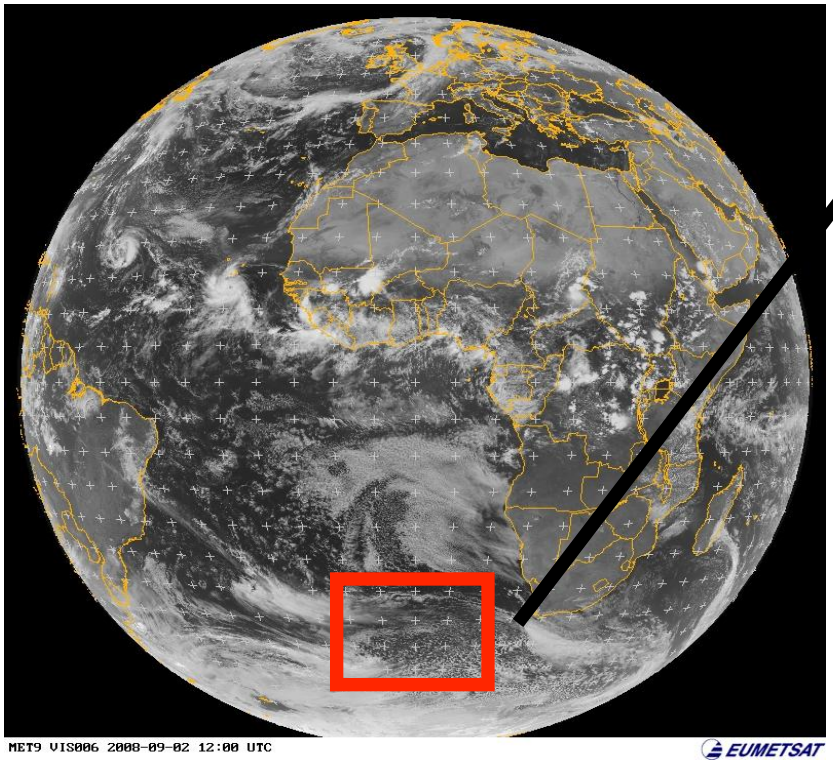


Min. Reflectivity, R_{min}, 12 UTC, Sept 2008



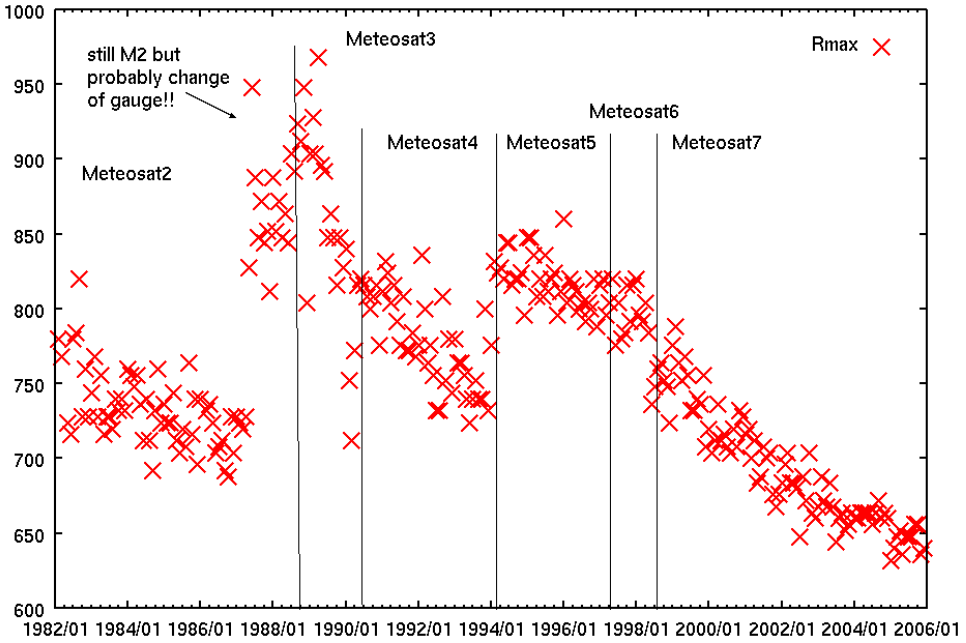
The Heliosat method

Reflectivity, 12 UTC, 2 Sept 2008



Max. reflectance, R_{max}:
95 % percentile of counts during one month in the reference region

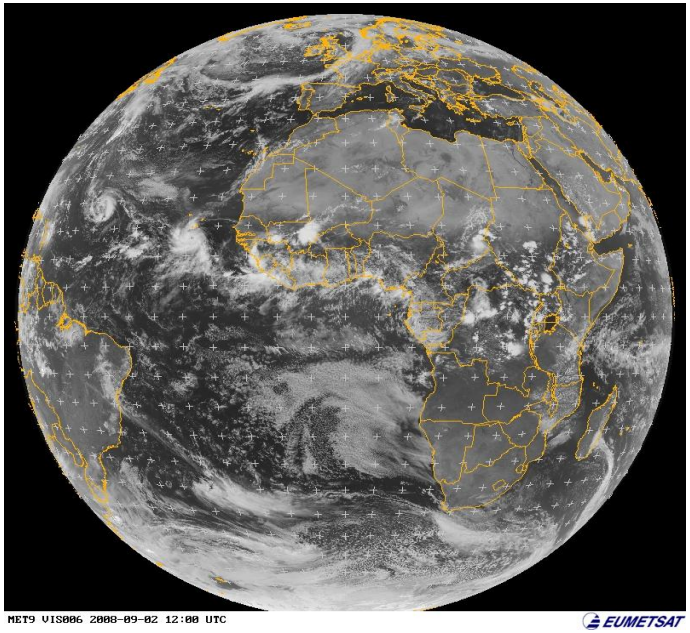
Temporal evolution of R_{max}



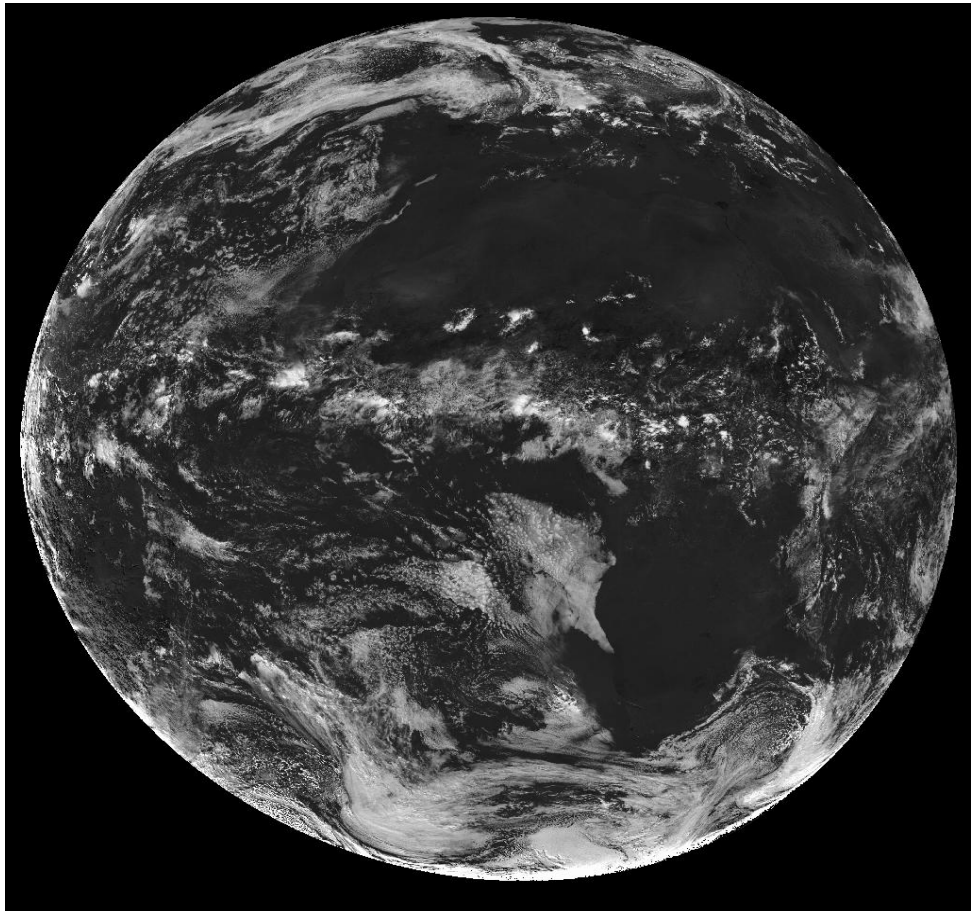
The Heliosat method

The definition of the Cloud Index n:

$$n = \frac{R - R_{min}}{R_{max} - R_{min}}$$

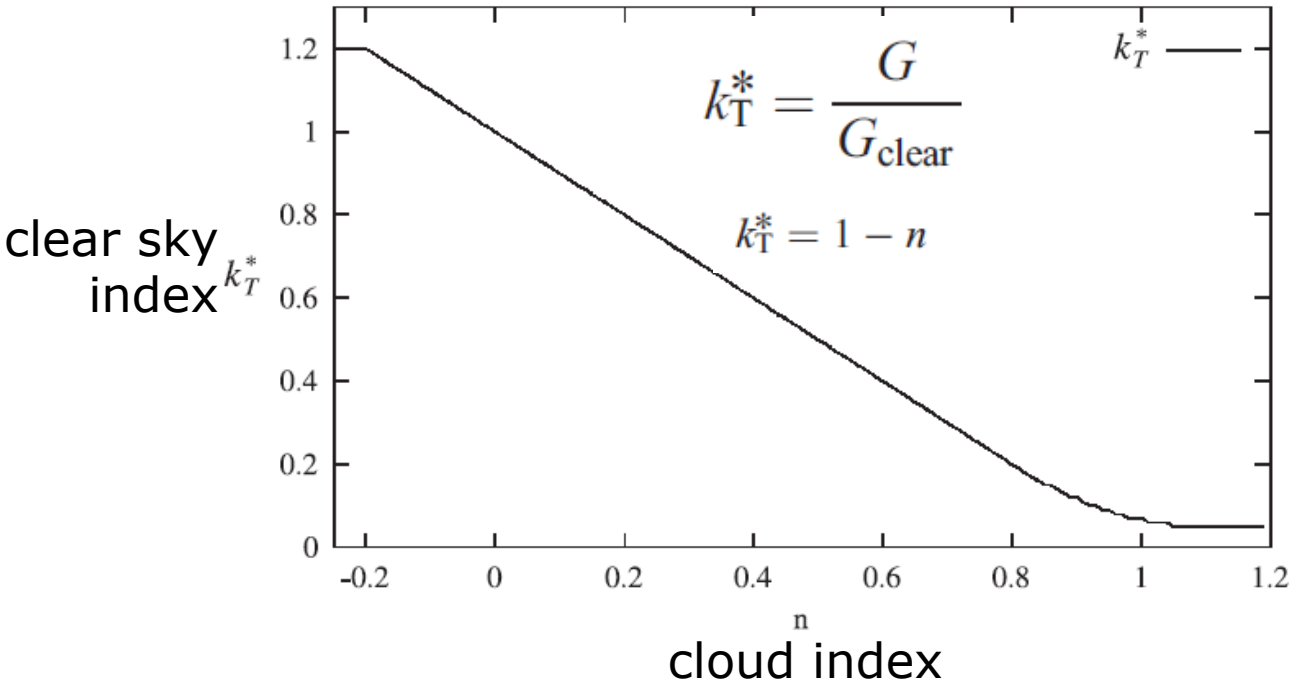


Cloud Index, 11 UTC, 1 July 2005



The Heliosat method

- The cloud index, n, is related to the clear-sky index, k.
- The clear-sky index, k, is the ratio between the all-sky surface irradiance, G, and the clear-sky surface irradiance, G_{clear}



The Heliosat method

- The cloud index, n, is related to the clear-sky index, k:

$$k = 1 - n$$

- The clear-sky index, k, is the ratio between the all-sky surface irradiance, G, and the clear-sky surface irradiance, G_{clear}:

$$G = k * G_{clear}$$

- G_{clear} can be calculated by radiation transfer calculations using the fast and accurate clear-sky model ***gnu-MAGIC*** *(Mesoscale Atmospheric Global Irradiance Code, Mueller et al., 2009,* http://sourceforge.net/projects/gnu-magic/)